fee now required by 37 C.F.R. 1.17(a)(1), reduced by half for applicant's small entity status.

The Commissioner is hereby further authorized to charge Deposit Account No. 14-1431 for any additional fees which may now be due under 37 C.F.R. 1.16 or 1.17.

In response to the Official Action dated October 21, 2003, please amend the above-identified application, as follows:

IN THE SPECIFICATION:

Please amend the paragraph beginning on page 11 at line 14 as follows:

--Further, according to the present invention, in a non-oxidizing reduction combustion method ~~defined in claim 1~~, combustion air is preheated to a high temperature close to a temperature of combustion exhaust gas by collecting heat of combustion exhaust gas exhausted through a regenerative medium, and then supplied. Further more, according to a burner of the present invention, in the non-oxidizing reduction combustion burner ~~defined in any of claims 9 to 19~~, an air throat includes a regenerative medium and flow path switching means which alternately leads combustion exhaust gas and combustion air to the regenerative medium, and combustion air preheated to a high temperature close to a combustion exhaust gas temperature is injected into a furnace through a regenerator.--

B1

Please amend each paragraph of the specification appearing between page 13, line 4 through page 16, line 25 as follows:

--Moreover, according to the present invention ~~defined in claim 3~~, in a non-oxidizing reduction combustion method ~~according to claim 1 or 2~~, combustion air is formed into a jet flow which is flat and has a thin thickness as a whole. In this case, the dilution effect by combustion gas is further enhanced by great increase in a specific surface area of the air jet flow, and a flow part having the high oxygen density/a jet flow having no core is formed when air collides with fuel. Thus, with the air ratio of less than 1, initial mixing can be rapidly performed and combustion can be carried out without having the high oxygen density parts but with the low oxygen density parts as a whole in the range of sufficient turbulence strength. As a result, an amount of soot to be generated can be reduced as much as possible, and occurrence of NOx can be also suppressed. In addition, in case of turbulent diffusion combustion with the air ratio of not less than 1, the short flame can be realized without increasing NOx.

Additionally, according to the present invention ~~defined in claim 4~~, in a non-oxidizing reduction combustion method ~~according to any of claims 1 to 3~~, fuel is injected from at least two injection openings and caused to collide with an air jet flow having an increased specific surface area in a wide area, and this fuel is rapidly mixed with the air jet flow with the strong turbulences. In this case, a contact area between air and fuel is also increased, and mixing can be effected at a higher speed. Therefore, with the air ratio of less than 1, an amount of free O_2 can be reduced as much as possible, and generation of unburned soot can be decreased as much as possible. Further, generation of NOx can be also suppressed, thereby realizing the short flame without increasing NOx with the air ratio of not less than 1.

Furthermore, according to the present invention ~~defined in claim 5~~, in a non-oxidizing reduction combustion method ~~according to any of claims 1 to 4~~, a plurality of fuel

jet flows are formed, and the fuel jet flows collide with each other before colliding to the air jet flow. In this case, since a flat fuel jet flow which flatly spreads can be obtained when the fuel jet flows collide with each other before coming in contact with the air jet flow, a contact surface area between fuel and high-temperature furnace gas is increased. As a result, the fuel jet flow is diluted/preheated (condition of a furnace temperature of not less than 800°C) at a position away from a fuel injection portion by a very short distance as compared with a case of a circular jet flow. Therefore, fuel has a high temperature, and a calorific value is sufficiently low. Furthermore, combustion air also has a high temperature and includes no part having the high oxygen density. Thus, even if rapid initial mixing is carried out with the strong turbulences, the stability of an ignition source can be maintained in a wide range of the supplied air temperature, and the combustion reaction is accelerated. Moreover, a quantity of free O_2 can be greatly decreased and an amount of soot to be produced can be reduced as much as possible.

Additionally, according to the present invention ~~defined in claim 6~~, in a non-oxidizing reduction combustion method ~~according to any of claims 1 to 4~~, a plurality of air jet flows are formed, and the air jet flows collide with each other before coming in contact with a fuel jet flow. In this case, a flat air jet flow which flatly spreads can be obtained when the air jet flows collide with each other before coming in contact with the fuel jet flow. Thus, as a result of increase in a contact surface area with respect to the high-temperature furnace gas, combustion air can be diluted/preheated (condition of the furnace temperature of not less than 800°C) by combustion gas without being greatly distanced from the air injection portion as compared with a case of a circular jet flow. At this moment, since combustion air has a high temperature and the oxygen density is sufficiently lowered so that there is no part with the high oxygen density, even if combustion air is mixed with fuel in that state,

the stability of an ignition source can be maintained in a wide range of the supplied air temperature, and combustion generating no area having a locally high temperature can be formed. At the same time, the combustion reaction is accelerated and an amount of free O_2 can be reduced as much as possible, and minimization of a quantity of soot to be generated can be realized. With the air ratio of not less than 1, the short flame can be realized without increasing NOx.

Further, according to the present invention, in a non-oxidizing reduction combustion method ~~defined in any of claims 1 to 4~~, a plurality of fuel jet flows and air jet flows are formed, the air jet flows collide with each other and the fuel jet flows collide with each other before the fuel jet flows come in contact with the air jet flows. In this case, since a flat jet flow which flatly spreads can be obtained when the fuel jet flows collide with each other before coming in contact with the air jet flows, a contact surface area between fuel and high-temperature furnace gas is increased. Consequently, the fuel jet flows are diluted/preheated (condition of the furnace temperature of not less than 800°C) without largely distanced from the fuel injection portion as compared with a case of a circular jet flow. At the same time, the air jet flows are also formed into a flat jet flow which flatly spreads when the air jet flows collide with each other before coming in contact with the fuel jet flow, and hence a high temperature is obtained, and the oxygen density is sufficiently lowered. Accordingly, when fuel has a high temperature, and the calorific power is sufficiently decreased, combustion air has a high temperature and includes no locally high oxygen density part. Therefore, even if initial mixing is rapidly carried out with the strong turbulences, the stability of an ignition source can be maintained in a wide range of the supplied air temperature, and combustion generating no locally high temperature area can be formed. At the same time, the combustion reaction is accelerated. With the air ratio of

less than 1, an amount of free O_2 can be reduced as much as possible, and minimization of a quantity of soot to be produced can be realized. With the air ratio of not less than 1, the short flame can be realized without increasing NOx.

B2

Moreover, according to the present invention, in a non-oxidizing reduction combustion method ~~defined in any of claims 1 to 7~~, a plurality of pairs of the combustion jet flow and the air jet flow which collide with each other in the furnace are formed, thereby forming a large combustion field.--

Please amend each paragraph of the specification appearing between page 18, line 13 and page 23, line 2, as follows:

-- Moreover, according to the present invention defined in claim 13, a specific surface area can be increased by dividing the air throat into a plurality of small holes. In this case, the specific surface area can be readily greatly increased as compared with the air throat consisting of a single perfect circle, and the distribution of temperature can become flat by scattering of the flames.

B3

In addition, according to the present invention ~~defined in claim 14~~, the air throat is divided into a plurality of small holes and respective jet flows are arranged in a row so as to be connected to each other without being independent in order to form a jet flow having a flat cross sectional shape as a whole. In this case, the specific surface area becomes larger than that of a jet flow formed by the circular air throat and the oxygen density can be further rapidly decreased, as similar to the case of a flat rectangular throat.

Additionally, according to a burner of the present invention ~~defined in claim 15~~, a plurality of small holes form jet flows in which air jet flows collide with each other before coming in contact with fuel jet flows. In this case, since a plurality of flat jet flows which flatly

spread can be obtained by a plurality of small holes when air jet flows collide with each other before coming in contact with fuel jet flows, a contact surface area of the jet flows with respect to the high-temperature furnace gas can be greatly increased as compared with the case of a single flat jet flow. As a result, combustion air is diluted/preheated (condition of the furnace temperature of not less than 800°C) with a distance from the air injection portion being extremely reduced as compared with the case of the circular jet flow. At this moment, a jet flow having a flat cross sectional shape can be formed when air jet flows collide with each other even if a flat air throat is not used, and the same effects as those obtained by a jet flow from the flat air throat can be obtained. That is, since the combustion air has a high temperature and the oxygen density is sufficiently lowered with no high oxygen density portion being provided, the stability of an ignition source can be maintained in a wide range of the supplied air temperature and combustion is formed without forming a locally high temperature area even if combustion air is mixed with fuel in this state. At the same time, the combustion reaction is further accelerated to extremely reduce an amount of free O_2, thereby realizing minimization of generation of soot.

B3

Furthermore, according to the present invention ~~defined in claim 15~~, in a non-oxidizing reduction combustion burner ~~according to any of claims 9 to 14~~, a fuel nozzle has at least two injection openings so that fuel can collide in a wide area with an air jet flow having an increased specific surface area. In this case, a contact area of combustion air with respect to fuel can be increased, and initial mixing by turbulent diffusion can be rapidly and extensively effected.

Moreover, according to the present invention ~~defined in claim 16~~, in a non-oxidizing reduction combustion burner ~~according to any of claims 9 to 14~~, the fuel nozzle has at least two injection openings so that a jet flow in which fuel jet flows emitted from respective

injection openings collide with each other before coming in contact with an air jet flow is formed. In this case, since a flat jet flow which flatly spreads can be obtained when the fuel jet flows collide with each other before coming in contact with an air jet flow, a contact surface area between the fuel and the high-temperature furnace gas is increased. As a result, the fuel jet flows are diluted/preheated (condition of the furnace temperature of not less than 800°C) with a distance from the fuel injection portion being extremely reduced as compared with the case of a circular jet flow. Therefore, fuel has a high temperature and a calorific value is sufficiently low. In addition, combustion air also has a high temperature and there is no part having the high oxygen density. Thus, even if initial mixing is rapidly carried out with the strong turbulences, the stability of an ignition source can be maintained in a wide range of the supplied air temperature, and the combustion reaction is accelerated, and an amount of free O_2 can be reduced as much as possible, and minimization of generation of soot can be realized.

B3

In addition, according to the present invention~~ defined in claim 17~~, in a non-oxidizing reduction combustion burner~~ according to any of claims 9 to 16~~, a plurality of fuel nozzles are arranged so as to surround an air jet flow. In this case, a contact area of air with respect to fuel can be increased, and initial mixing by turbulent diffusion can be extensively and rapidly performed.

Additionally, according to the present invention~~ defined in claim 19~~, in a non-oxidizing reduction combustion burner~~ according to claim 18~~, a plurality of fuel nozzles form a jet flow in which fuel jet flows collide with each other before coming in contact with an air jet flow. In this case, since a flat jet flow which flatly spreads can be obtained when fuel jet flows collide with each other before coming in contact with an air jet flow, a contact surface area between the fuel and the high-temperature furnace gas is increase. As a result, the

fuel jet flows are diluted/preheated (condition of the furnace temperature of not less than 800°C) with a distance from the fuel injection portion being extremely reduced as compared with the case of circular jet flow. Therefore, fuel has a high temperature, and a calorific value is sufficiently lowered. Also, combustion air has a high temperature and there is no part having the high oxygen density. Thus, even if rapid initial mixing is performed with the strong turbulences, the stability of an ignition source can be maintained in a wide range of the supplied air temperature, and the combustion reaction is accelerated, and an amount of free O_2 can be reduced as much as possible, and minimization of generation of soot can be realized.

B3

In addition, according to the present invention, in a non-oxidizing reduction combustion burner ~~defined in any of claims 11 to 19~~, a plurality of air jet flows and fuel jet flows are formed, and there are formed jet flows in which the air jet flows collide with each other while the fuel jet flows collide with each other before the air jet flows come in contact with the fuel jet flows. In this case, it is possible to obtain flat jet flows of fuel and combustion air which flatly spread when air jet flows collide with each other and fuel jet flows collide with each other before air jet flows and fuel jet flows come in contact with each other. Therefore, a contact surface area of the fuel and the high-temperature furnace gas and that of the combustion air and the furnace gas are greatly increased as compared with the case of the circular jet flows. As a result, the fuel and the combustion air are diluted/preheated (condition of the furnace temperature of not less than 800°C) with a distance being extremely reduced from each injection portion. Thus, the fuel has a high temperature, and a calorific value is sufficiently lowered. Also, the combustion air has a high temperature, the oxygen density is satisfactorily decreased, and there is no part having a locally high temperature portion. Therefore, even if the fuel and the combustion

air are subjected to initial mixing with the strong turbulences, the stability of an ignition source can be maintained in a wide range of the supplied air temperature, and combustion formation can be obtained without generating a locally high temperature area. At the same time, the combustion reaction is accelerated, and an amount of free O_2 can be reduced as much as possible, and minimization of generation of soot can be realized.

B3

Please amend each paragraph of the specification appearing beginning at page ~~23~~ 24, line 13 through page 25, line 8 as follows:

--Moreover, according to the present invention ~~defined in claim 22~~, in a non-oxidizing reduction combustion burner ~~according to claim 21~~, a ceramic honeycomb is included as a regenerative medium. Here, it is preferable that the number of cells of the honeycomb is 10 to 200 cells/in^2. In this case, the pressure loss is much lower than that of a regenerator in which nuggets or blocks are filled. Therefore, even if soot and the like is generated, the performance is hardly deteriorated by clogging or fouling of such soot. Further, since the pressure loss is small, the combustion air can be injected into the furnace at a high speed by the low supply power. Thus, the gas in the furnace can be actively agitated to encourage uniformization of the furnace temperature distribution, and generation of NOx is suppressed. Also, convection heat transfer between the regenerator and the air or the exhaust gas flowing in the regenerative medium at a high speed without turbulences can be improved, and it is possible to follow up changes in temperature in a very short time by a thin cell thickness as compared with the case of a regenerator having, e.g., nuggets. Therefore, a high-speed switching is enabled with the capability as the regenerator being fully utilized, and the temperature efficiency of heat exchange can be increased. Furthermore, the furnace temperature can be increased or decreased within a

B4

short time, and preheated air having a high temperature is supplied to improve the energy saving effect.

Moreover, according to the present invention~~ defined in claim 23~~, in a non-oxidizing reduction combustion burner~~ according to claim 21 or 22~~, the regenerative medium is included in the air throat of a burner body, and flow switching means is directly connected to the burner body so that combustion air and exhaust gas are switched very near the burner body. In this case, an air supply delay time of air charging/exhaust at the time of burner switching is minimized, and the CO density is stabilized. At the same time, an amount of free O_2 at the time of switching is reduced as much as possible. That is, a purge capacity for a duct between the regenerative medium and the flow switching means is no longer necessary, and an amount of exhaust gas remaining in that duct is thereby also reduced. A quantity of purge air at the time of switching becomes very small. Therefore, the oxygen density can be prevented from being increased, and it is possible to prevent the adverse effect of free O_2 in heat treatment and the like in which such high density should be avoided.

B4

Additionally, according to the present invention~~ defined in claim 28~~, in a non-oxidizing reduction combustion burner~~ according to any of claims 11 to 27~~, a plurality of pairs of an air throat and a fuel nozzle are set to constitute a large combustion machine. In this case, by arranging a plurality of pairs of the air throat and the throat which accommodates the fuel nozzle in, for example, an annular form arranging them in alignment in the vertical direction or the horizontal direction or arranging them radially according to needs, a large combustion machine can be constituted as the need arises.--

Please amend the paragraph beginning at page 27, line 17 as follows:

B5

--The mixing of fuel with air can be readily realized by the burner according to the invention. ~~claim 12~~. When the air throat and the fuel nozzle are arranged in this range, the fuel has the velocity energy which is necessary and sufficient for turbulent diffusion mixing involving strong turbulences, while the oxygen density of the combustion air is satisfactorily lowered. In this state, the fuel jet flow and the air jet flow are caused to collide with each other. And, according to the inventio~~n in claim 126~~, the fuel nozzle is can be arranged in a position where the fuel and the air are caused to collide with each other in the vicinity of the air injection opening without introducing mal-mixing of the air with the fuel. --

Please amend the paragraph beginning at page 28, line 6 as follows:

B6

--Furthermore, in a non-oxidizing reduction combustion method and a burner according to claims 2 and 13, the combustion air is preheated to a high temperature (i.e., the temperature close to an exhaust gas temperature) equal to or above a self-ignition temperature of mixed gas of air and fuel through the regenerative medium, and this combustion air having the oxygen density sufficiently decreased is caused to collide with the fuel having the velocity energy which is necessary and sufficient for turbulent diffusion mixing involving strong turbulences. Thus, a certain amount of energy can be obtained using a smaller amount of fuel while suppressing generation of NOx. Therefore, energy-saving can be effected. That is, a regenerative burner having the high energy saving effect can be applied to turbulent diffusion combustion. As a result, the flame length can be shortened approximately 10 to 30%, and an exhaust gas temperature at an outlet of the furnace can be lowered to a temperature close to an acid dew point, thereby enabling energy saving of 30% or above as compared with the prior art burner. Additionally, a

reduction ratio of a quantity of NOx to be generated can be reduced to 50% or lower as compared with the prior art by high-temperature air combustion, thus obtaining a very flat temperature distribution in the combustion field.--

B4

Please amend each paragraph of the specification appearing beginning at page 29, line 9 through page 32, line 11 as follows:

--Further, according to the non-oxidizing reduction combustion method and the burner in the invention~~ set forth in claims 3 and 12~~, since a specific surface area of the air jet flow is greatly increased as compared with a case of a circular jet flow and the dilution effect is further enhanced. Thus, a quantity of free O_2 can be greatly decreased and an amount of soot to be produced can se reduced as much as possible. Further, generation of NOx can be also suppressed.

B7

Furthermore, according to the non-oxidizing reduction combustion burner in the invention~~ set forth in claims 13 and 14~~, a specific surface area of the air jet flow is greatly increased as compared with a case of a circular jet flow, as well as a case of a flat rectangular throat and the dilution effect by the furnace gas can be further enhanced. As a result, generation of NOx can be further suppressed while enabling combustion to be carried out with an extremely small quantity of free O_2 due to the rapid initial mixing with strong turbulences.

Moreover, according to the non-oxidizing reduction combustion method and the burner in the invention~~ set forth in claims 4, 16 and 18~~, a contact area between the fuel jet flow and the air jet flow is increased and the air and the fuel can be well mixed. Thus, an amount of free O_2 can be greatly decreased and an amount of soot to be generated can be reduced as much as possible.

In addition, according to the non-oxidizing reduction combustion method and the burner in the invention~~ set forth in claims 5, 17 and 19~~, since a fuel jet flow which flatly spreads can be obtained when the fuel jet flows collide with each other before coming in contact with the air jet flow, a contact surface area between the fuel jet flow and the air jet flow is increased. As a result, the stability of an ignition source can be maintained in a wide range of the combustion air temperature from a low temperature to a high temperature, and the combustion reaction is accelerated at the same time. And, a quantity of free O_2 can be greatly decreased and an amount of soot to be produced can be reduced as much as possible.

B7

Further, according to the non-oxidizing reduction combustion method and the burner in the invention~~ set forth in claims 6 and 15~~, a flat air jet flow is effectively obtained in a short time/distance. Thus, a contact area between the air jet flow and the furnace gas is effectively increased so that the air is diluted /preheated by the furnace gas to be mixed with the fuel. At the same time, combustion can be stably performed without forming an area having a locally high temperature. And, an amount of free O_2 can be reduced as much as possible and minimization of a quantity of soot to be generated can be realized.

Furthermore, according to the non-oxidizing reduction combustion method and the burner in the invention~~ set forth in claims 7 and 20~~, since a contact area between the fuel and the furnace gas is effectively increased in a short time/distance and the fuel itself can be diluted and an effective calorific value is dropped, generation of locally high temperature areas can be prevented and generation of NOx can be suppressed.

Moreover, according to the non-oxidizing reduction combustion burner in the invention~~ set forth in claim 23~~, an air supply delay time of air charging/exhaust at the time of burner switching and a purge quantity is minimized so that switching at a high speed is

enabled. Thus, a time lag in the fuel injection is almost eliminated so that one of a pair of the burners can be extinguished while the other can be ignited. As a result, an amount of free O_2 at the time of switching can be reduced as much as possible. Therefore, the oxygen density can be prevented from being increased at the time of switching, and it is possible to reduce the adverse effect of free O_2 in heat treatment in which such high density should be avoided.

B1

In addition, ~~according to the invention in claim 22,~~ since a pressure loss is much lower than that of a regenerator in which nuggets, blocks or the like are filled, a high-speed switching is enabled with the capability as the regenerator being fully utilized, and the temperature efficiency of heat exchange can be increased. Furthermore, the furnace temperature can be increased or decreased within a short time, and preheated air having a high temperature is supplied to improve the energy-saving effect. In addition, when air and exhaust gas alternately flow in the regenerative medium having the honeycomb structure, they reciprocate without generating a local turbulent flow or a low flow velocity, and hence soot does not adhere or is not deposited. Accordingly, the regenerator does not have to be cleaned or replaced even if it is used for a long time, and the maintenance is unnecessary. Additionally, according to the present invention, the performance is hardly deteriorated by clogging or fouling of the regenerative medium which is caused due to occurrence of soot. Therefore, it is possible to enable minimization of generation of soot by a burner structure making the best use of the features of high-temperature air combustion and also suppression of NOx value and minimization of free O_2 (remaining O_2) by preventing locally high temperature areas from forming in the flame. --